

# A 3D SWAP-STEREO RECONSTRUCTION OF A MASS-LOADING ERUPTION

Dan Seaton, Marilena Mierla, David Berghmans,  
Laurent Dolla, & Andrei Zhukov  
**Royal Observatory of Belgium**

17 November 2010 ☀ ESWW7

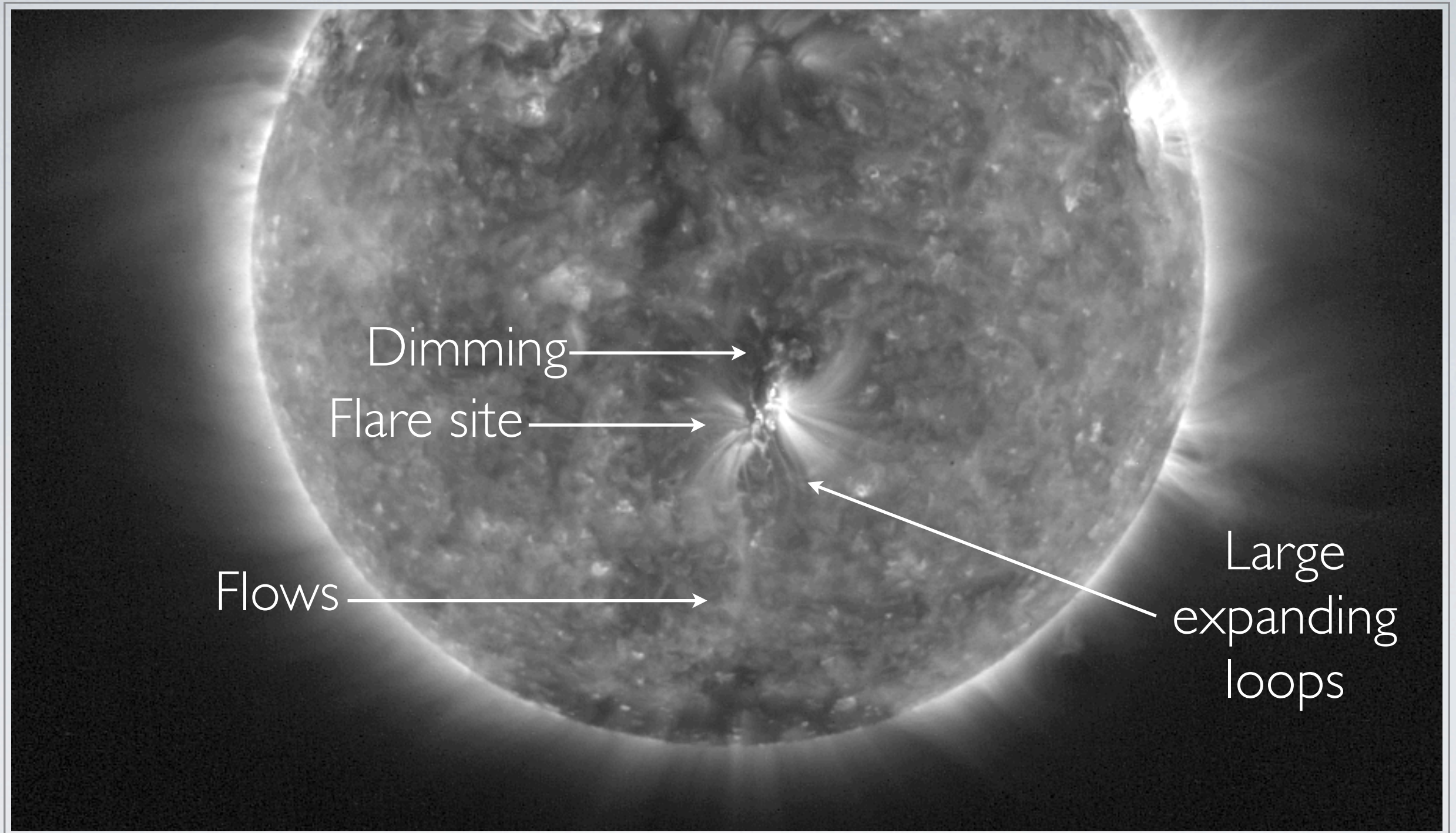




# PROBA2 & SWAP

Sun **W**atcher with **A**ctive Pixels and Image **P**rocessing





# ERUPTION & FLARE

3 April 2010, 09:30 UTC ☀ B7.4 Flare ☀ Geoeffective CME



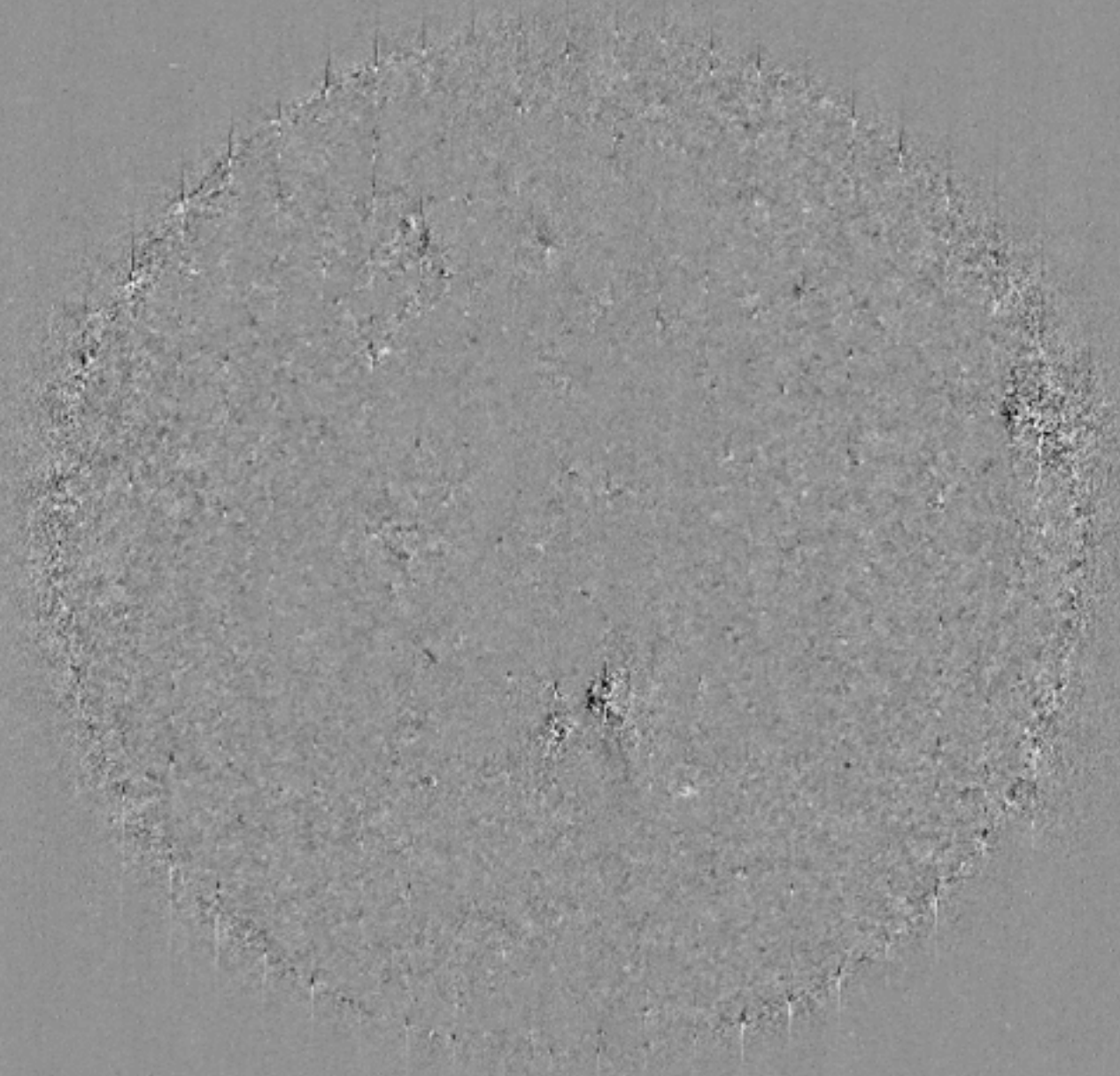




SWAP 175 Å 2010-04-03 08:00:31







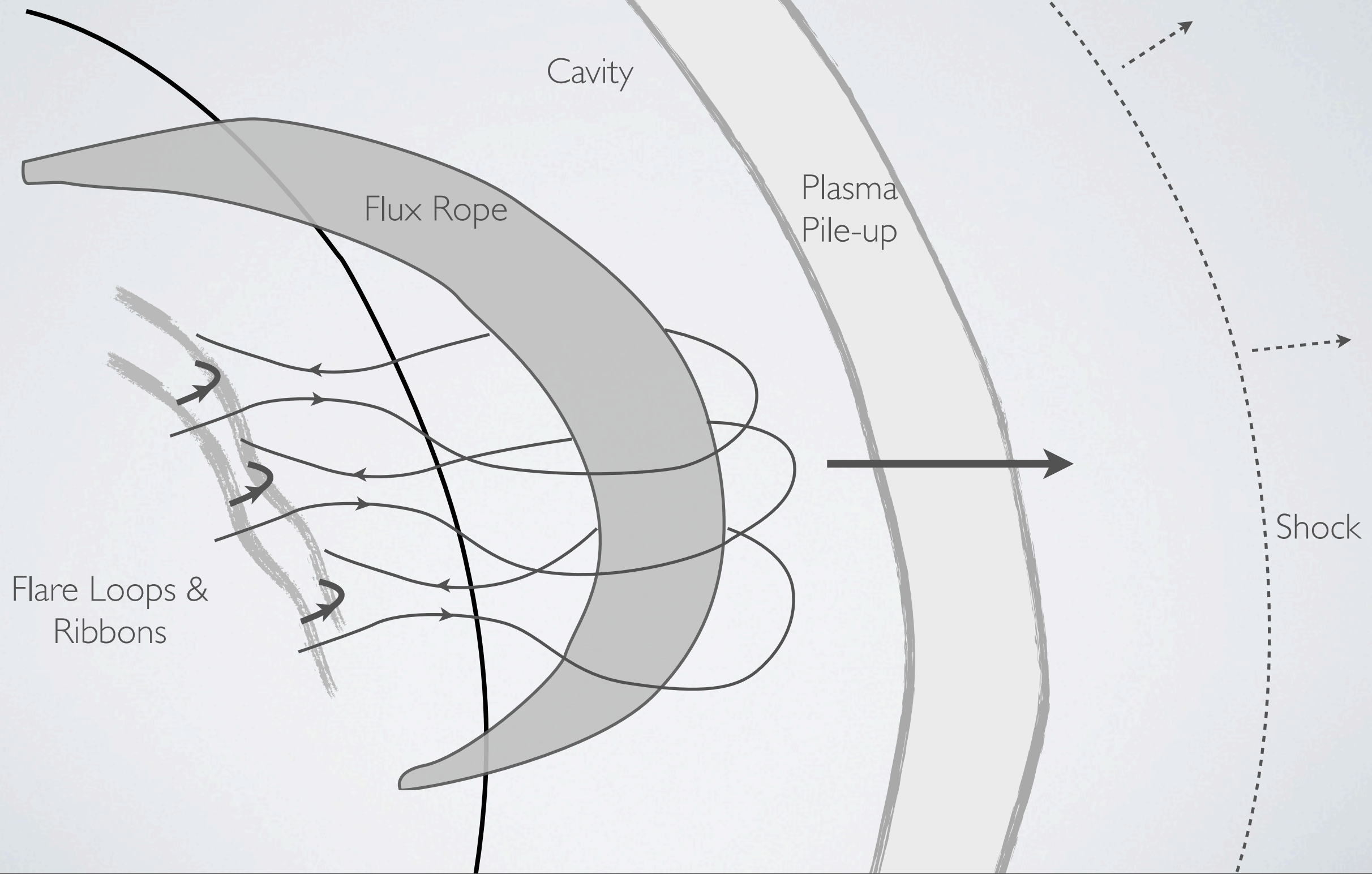
SWAP 175 Å 2010-04-03 08:02:11

**CENTRAL QUESTION:**  
WHAT CAUSED THIS  
SOLAR ERUPTION?



WHAT DO WE KNOW  
ABOUT ERUPTIONS?

# SOLAR ERUPTIONS





# ENERGETICS

## Energies:

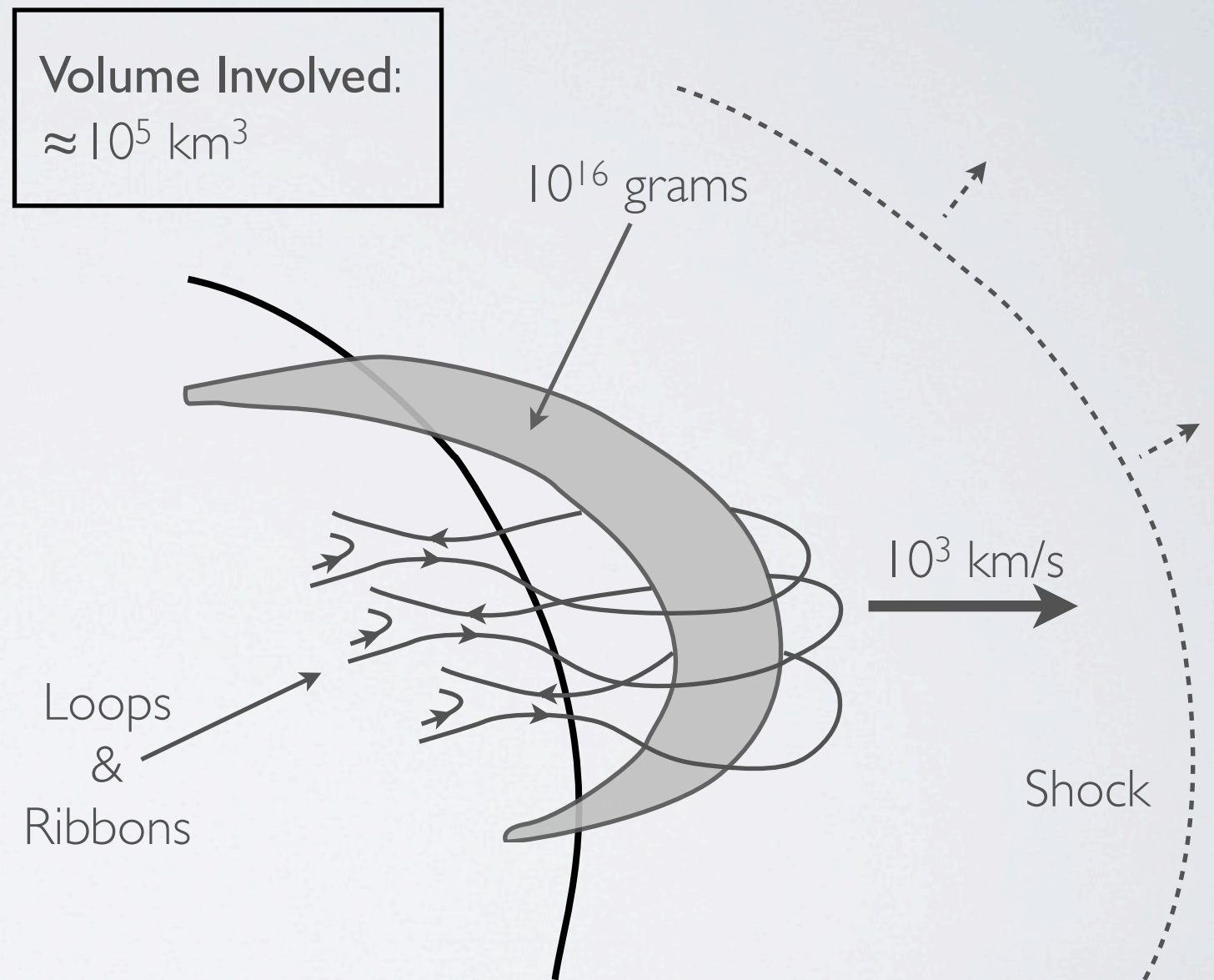
Kinetic:  $\approx 10^{32}$  ergs

Heat:  $\approx 10^{32}$  ergs

Work against gravity:  
 $\approx 10^{31}$  ergs

## Energy Density:

$\approx 100$  ergs/cm<sup>3</sup>



# ENERGETICS

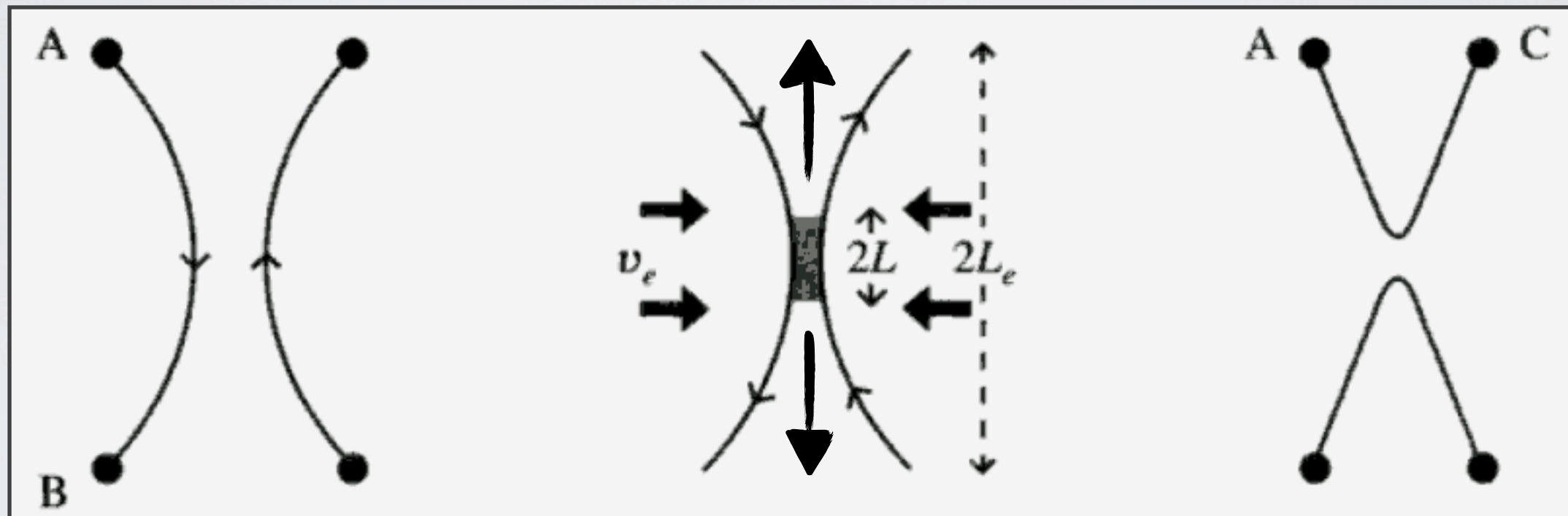
Nature of Energy Source:      Required:  $\approx 100 \text{ ergs/cm}^3$

Type	Observed Values	Energy Density
<b>Kinetic</b> $\frac{1}{2}(m_p n) v^2$	$n = 10^9 \text{ cm}^{-3}$ $v = 1 \text{ km/s}$	$10^{-5} \text{ erg/cm}^3$
<b>Thermal</b> $nkT$	$T = 10^6 \text{ K}$	$0.1 \text{ erg/cm}^3$
<b>Gravitational</b> $m_p n g h$	$h = 10^5 \text{ km}$	$0.5 \text{ erg/cm}^3$
<b>Magnetic</b> $B^2/8\pi$	$B = 100 \text{ G}$	$400 \text{ erg/cm}^3$



# ENERGETICS

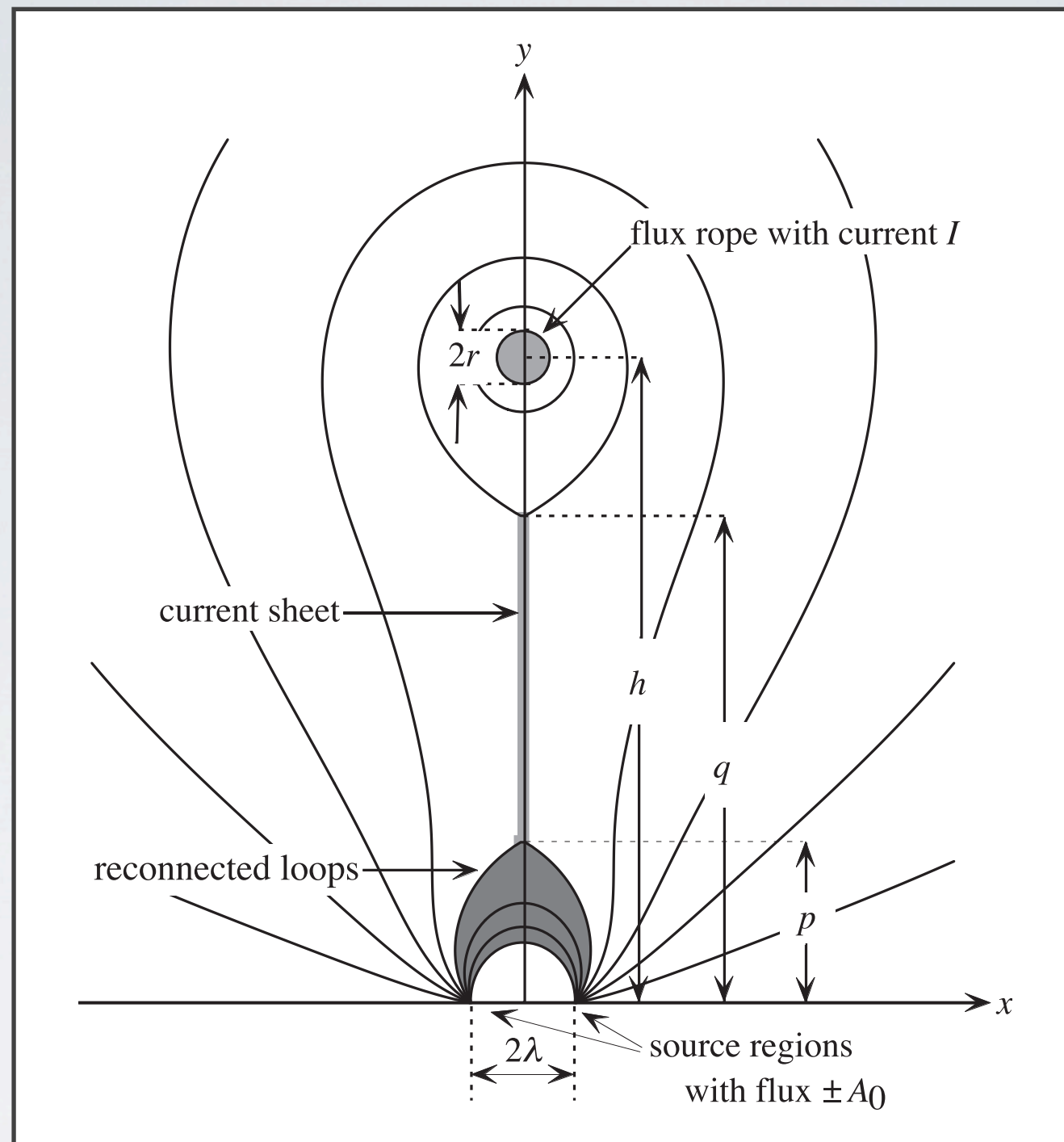
Reconnection Releases Stored Magnetic Energy



Ideal MHD:  
Topology can't  
change

Diffusion region  
forms, plasma &  
field decouple

Reconnected field  
has lower potential  
energy

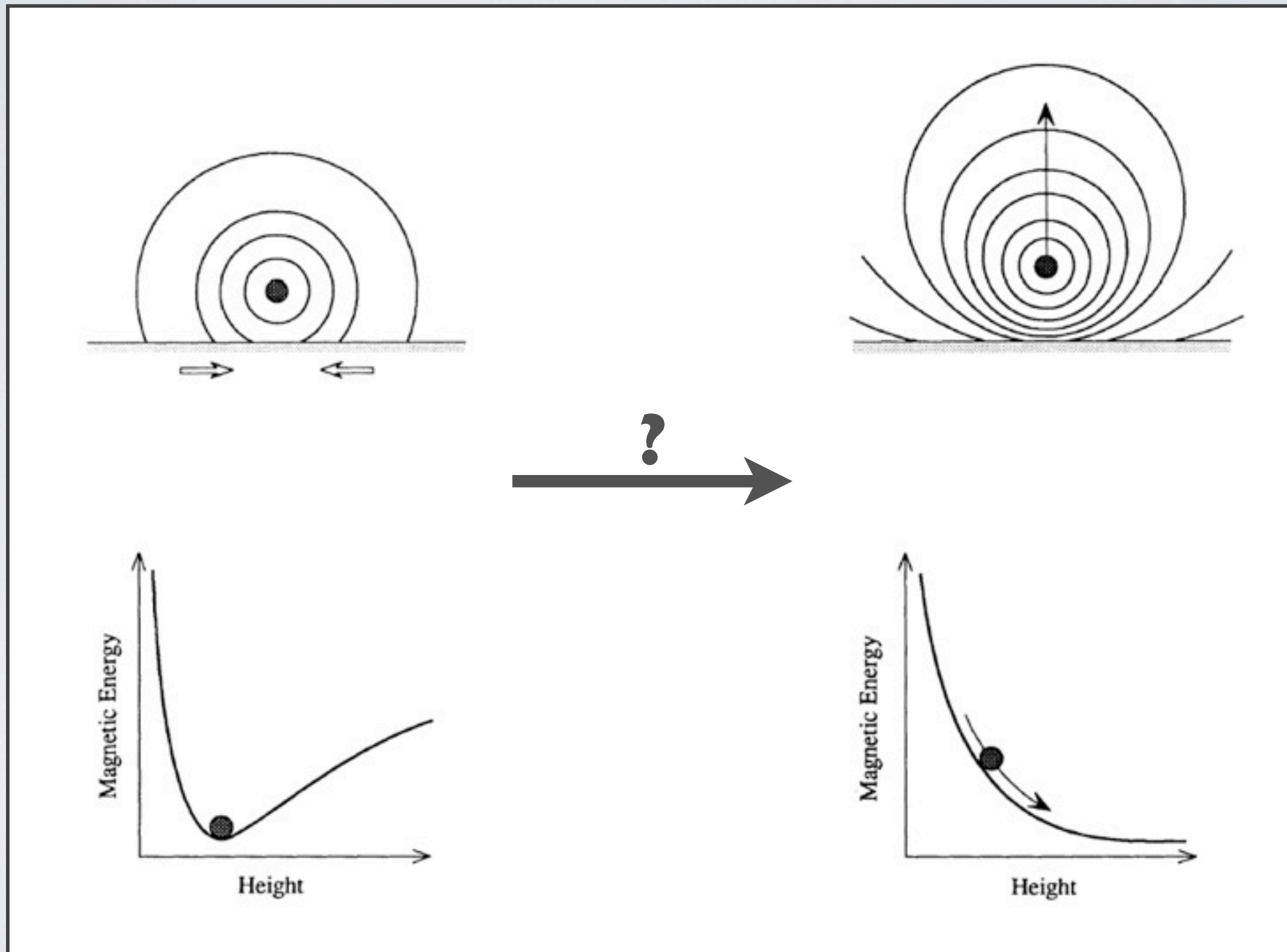


# ERUPTION MODELS

Schematic of an Erupting Flux Rope



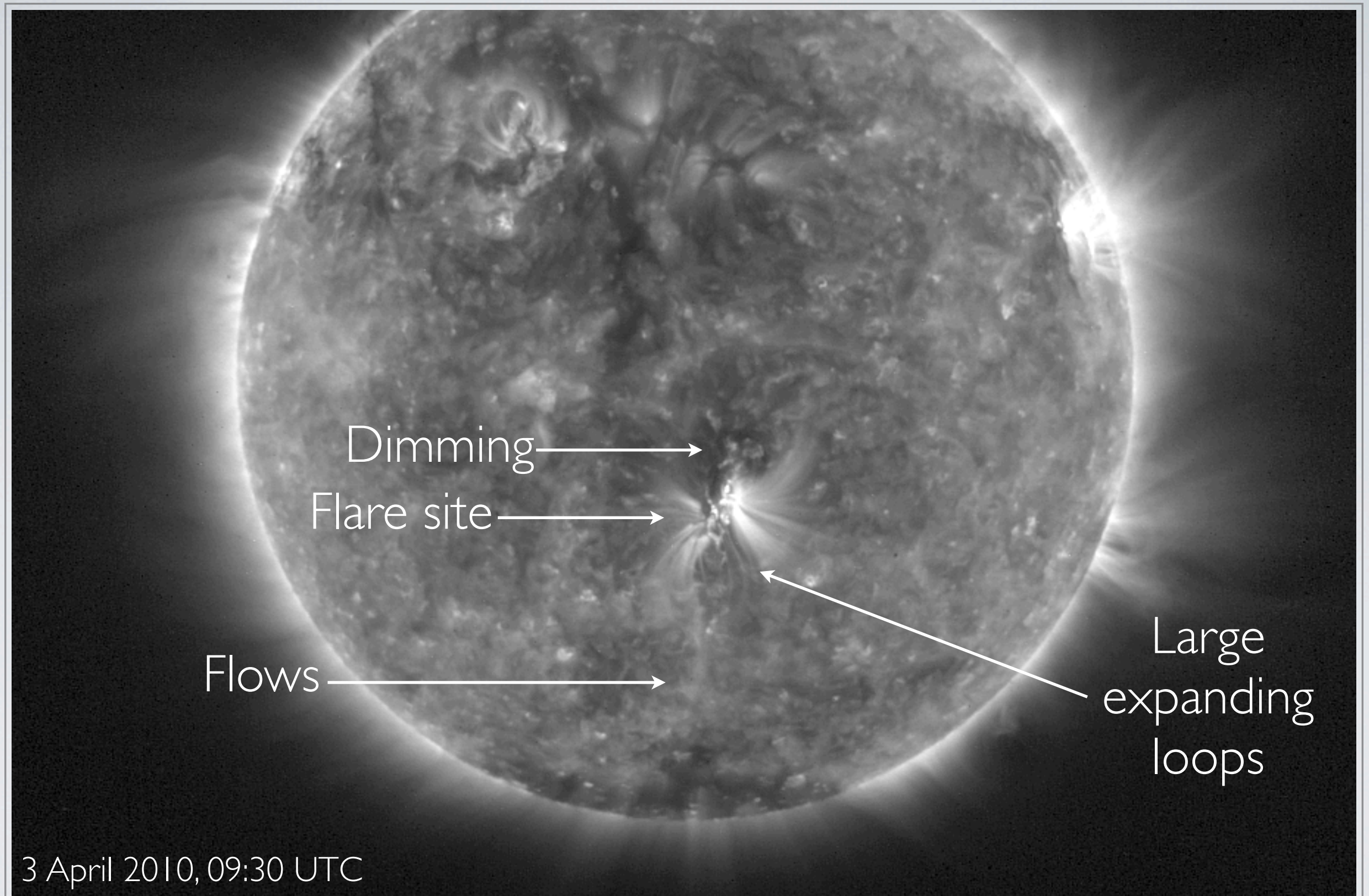
# LOSING EQUILIBRIUM



WHAT TRIGGERED THIS L.O.E.  
FOR THE 3 APRIL EVENT?

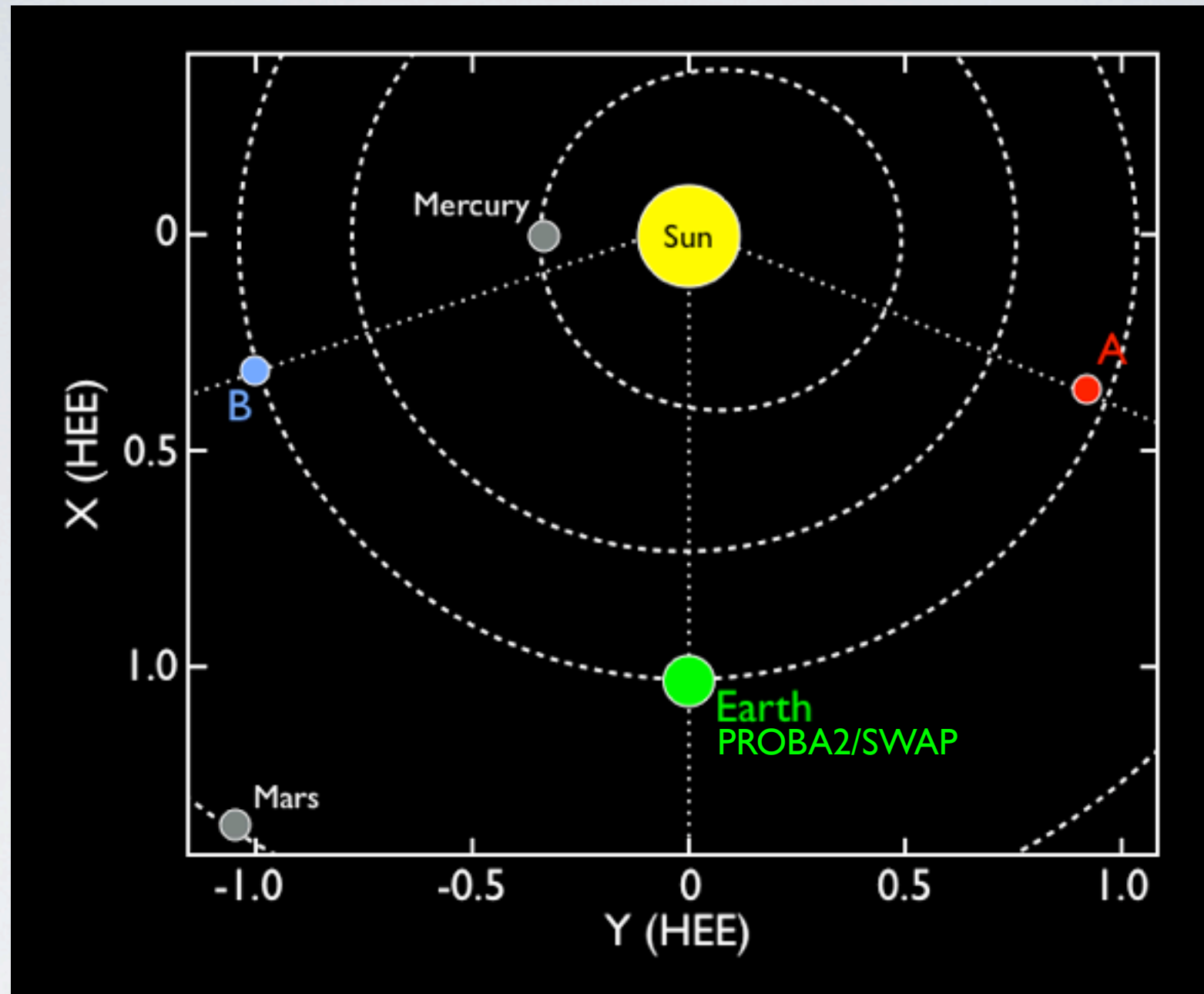


# OBSERVATIONS



# SWAP OBSERVATIONS





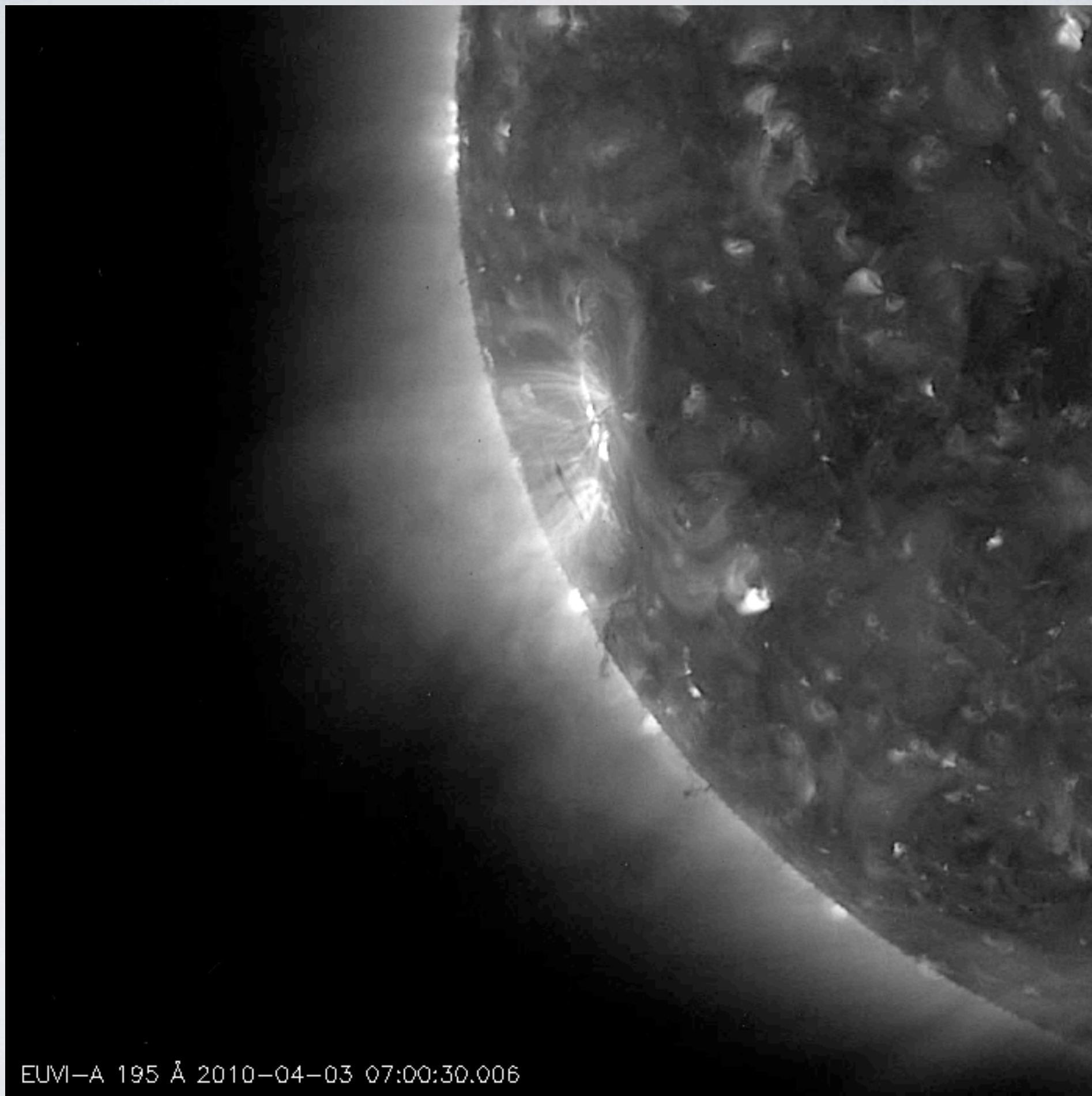
# STEREO & PROBA2

STEREO-A Separation Angle:  $67.4^{\circ}$

STEREO-B Separation Angle:  $71.2^{\circ}$

EUVI-A 195 Å

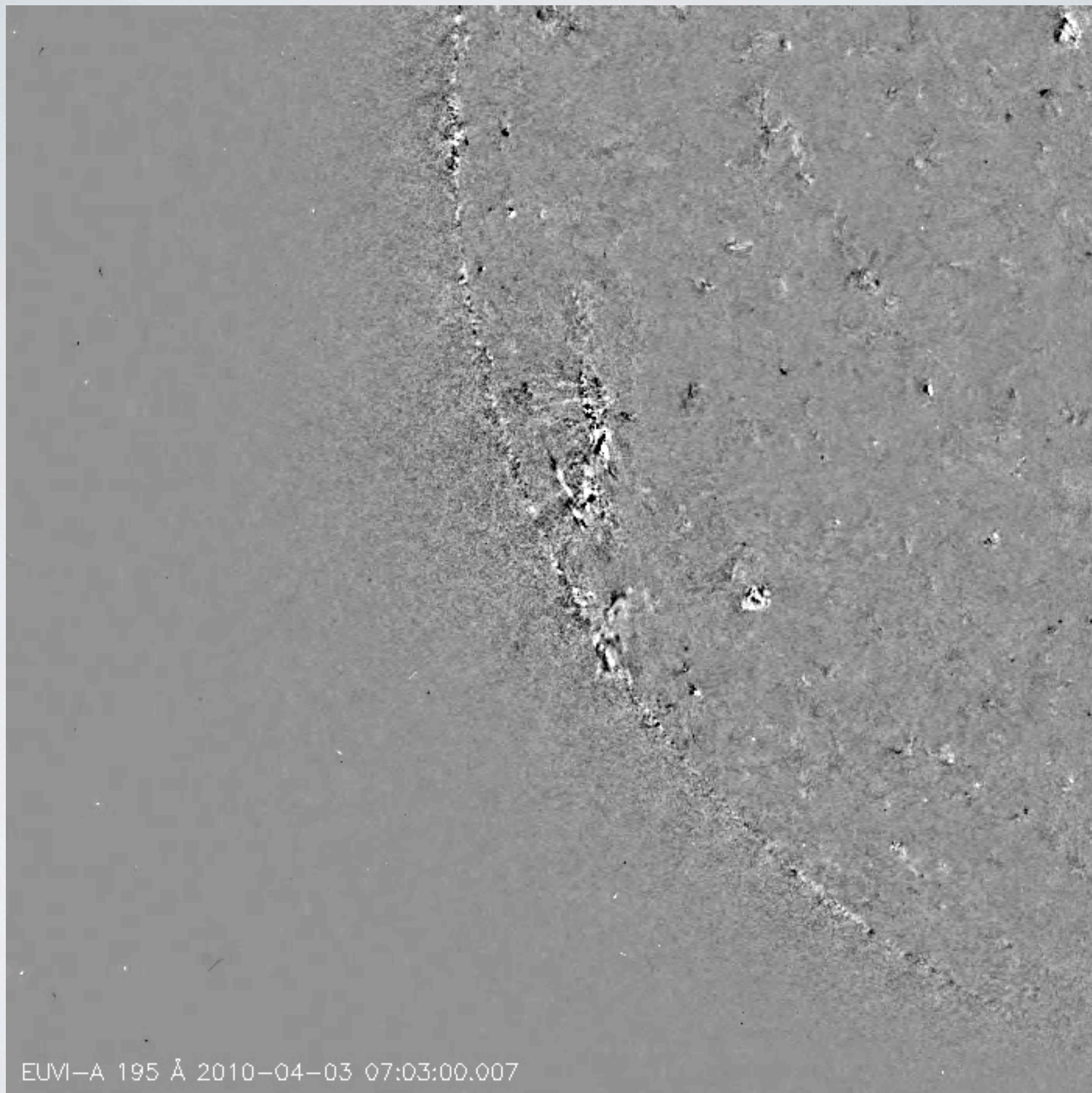




EUVI-A 195 Å 2010-04-03 07:00:30.006

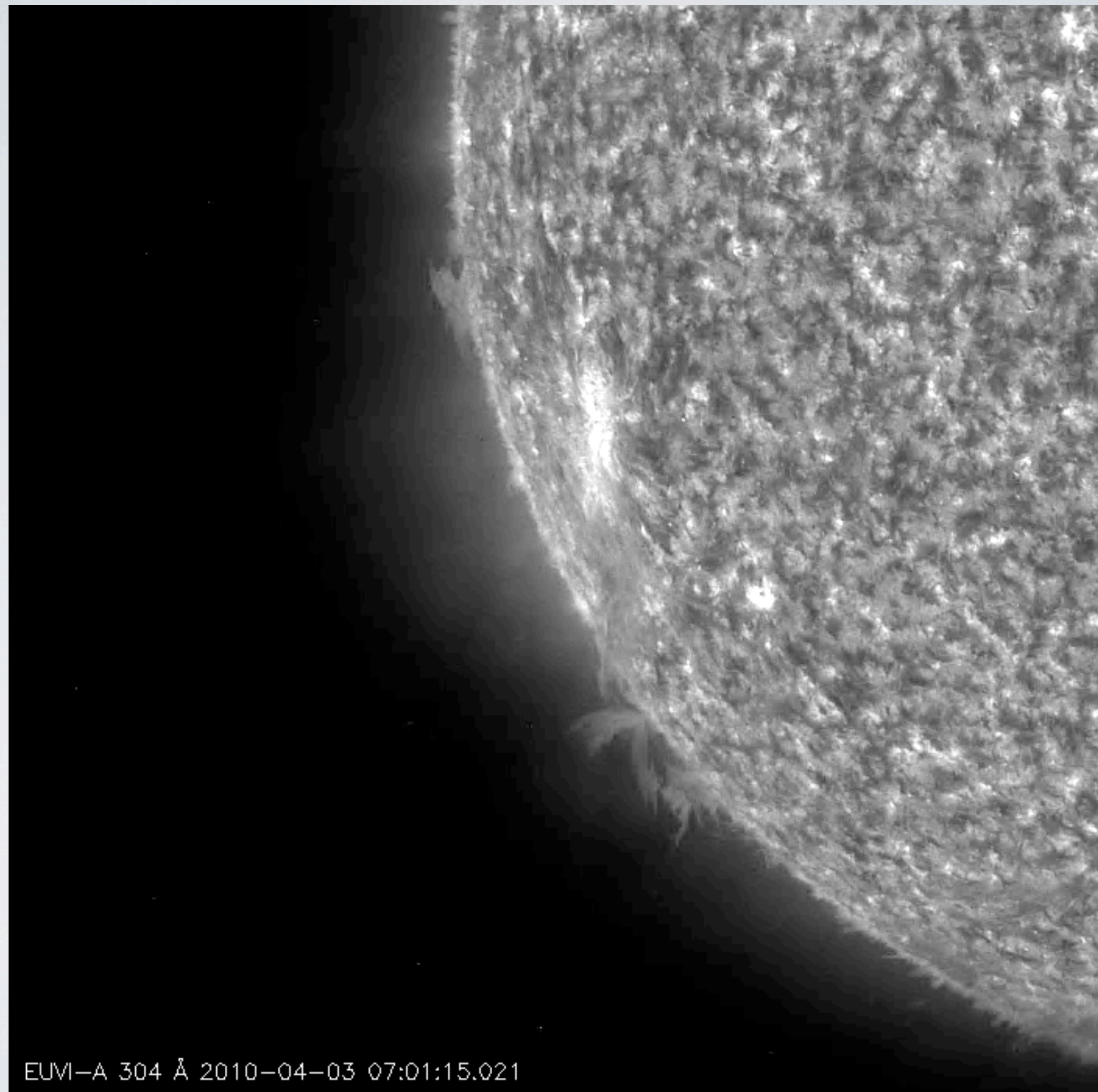






EUVI-A 304 Å





EUVI-A 304 Å 2010-04-03 07:01:15.021

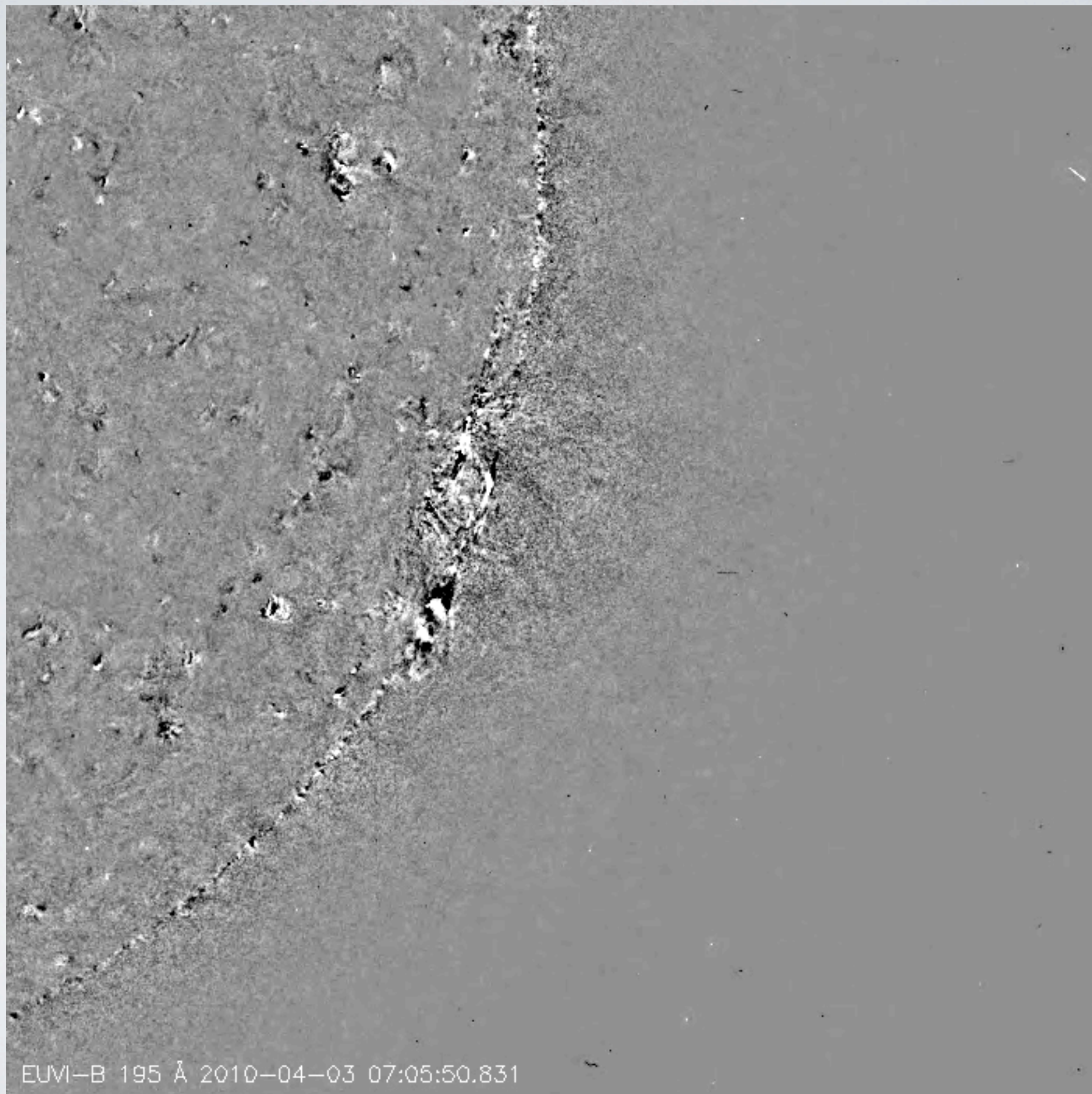
EUVI-B 195 Å







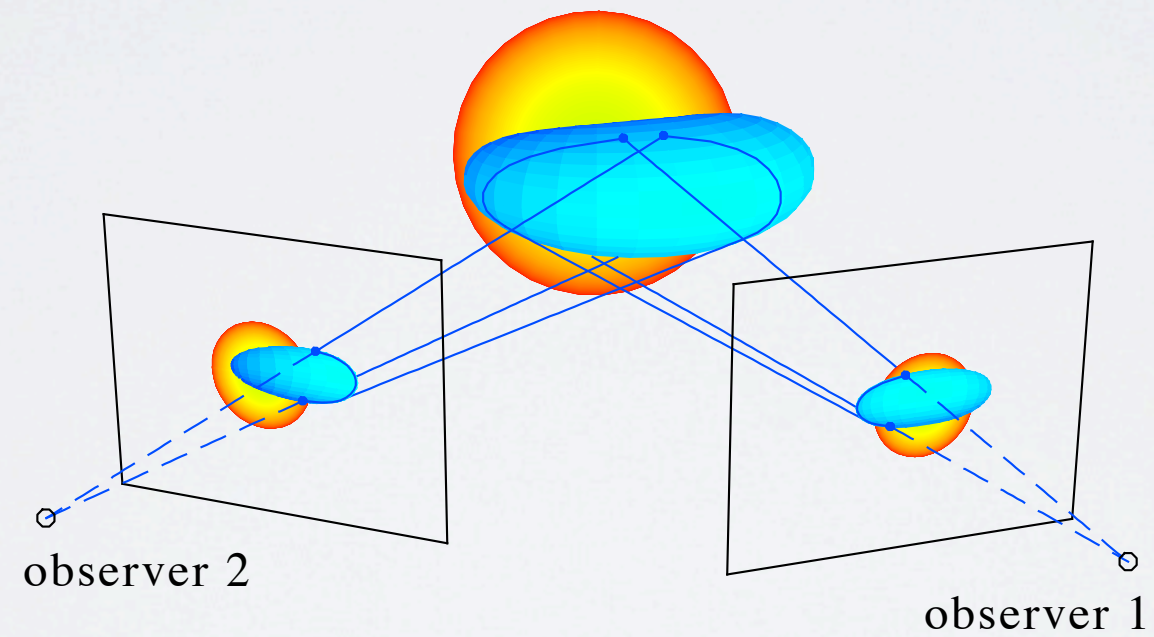
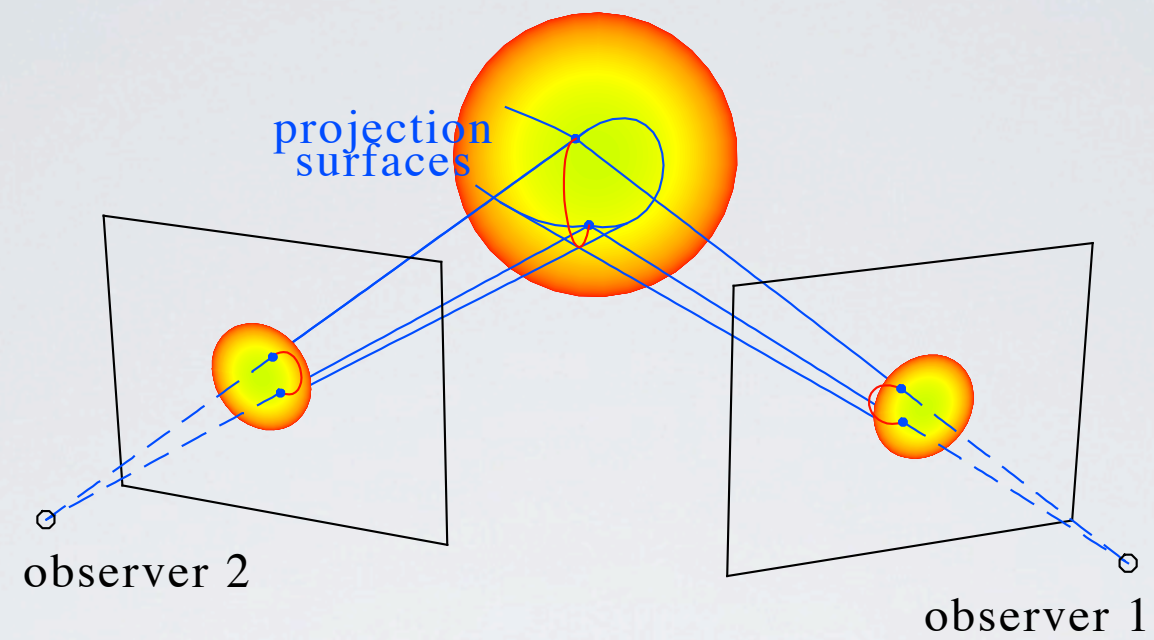




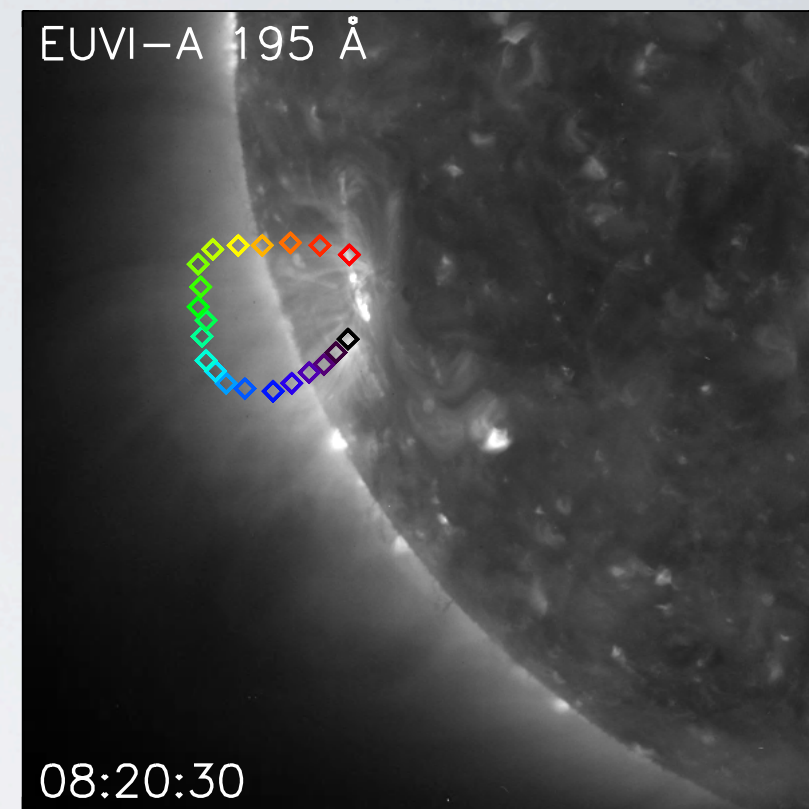
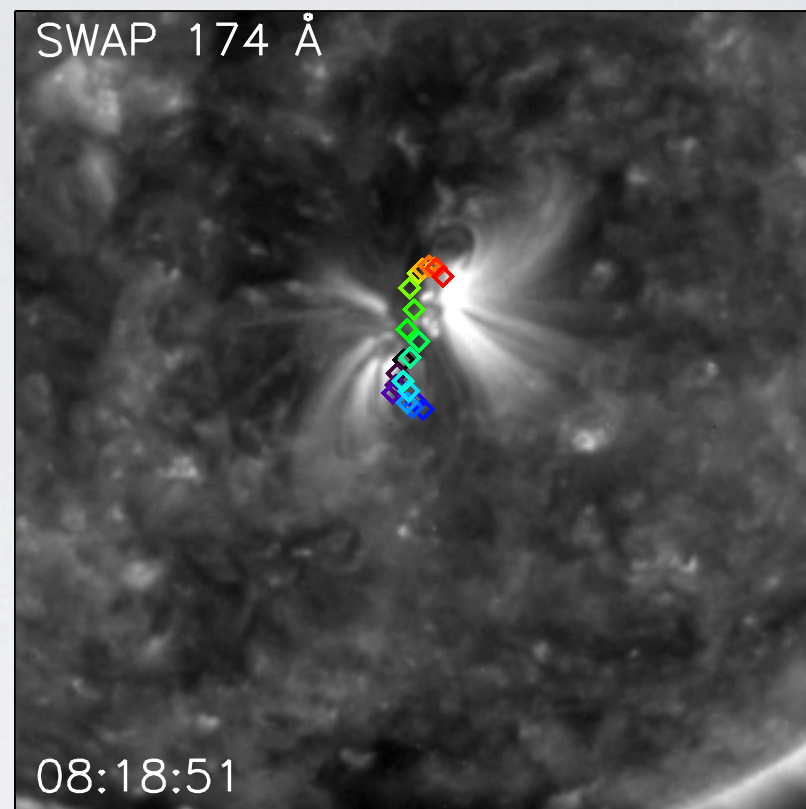
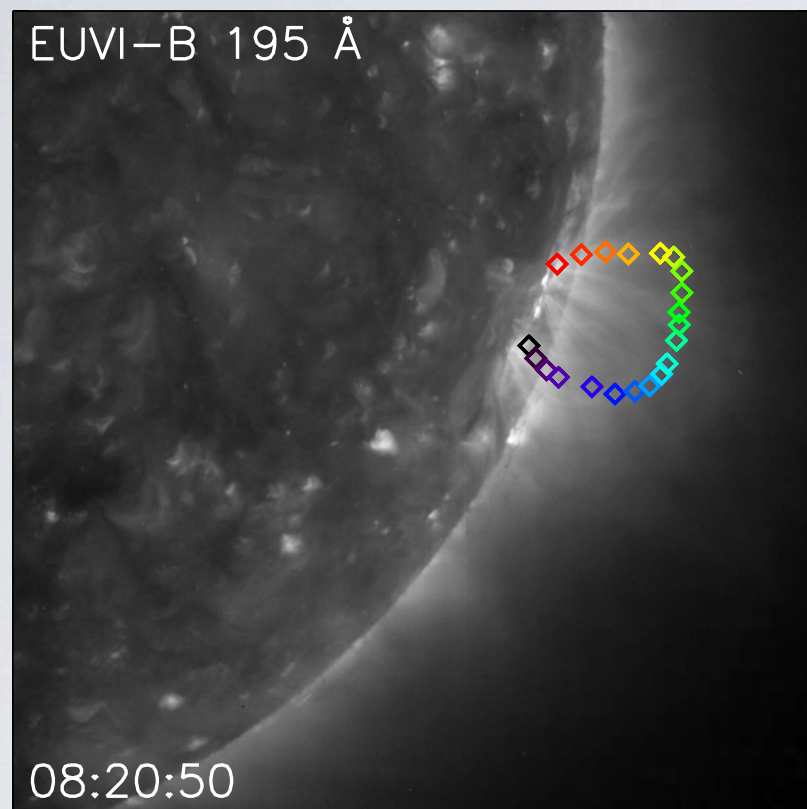
EUVI-B 195 Å 2010-04-03 07:05:50.831

# RECONSTRUCTIONS





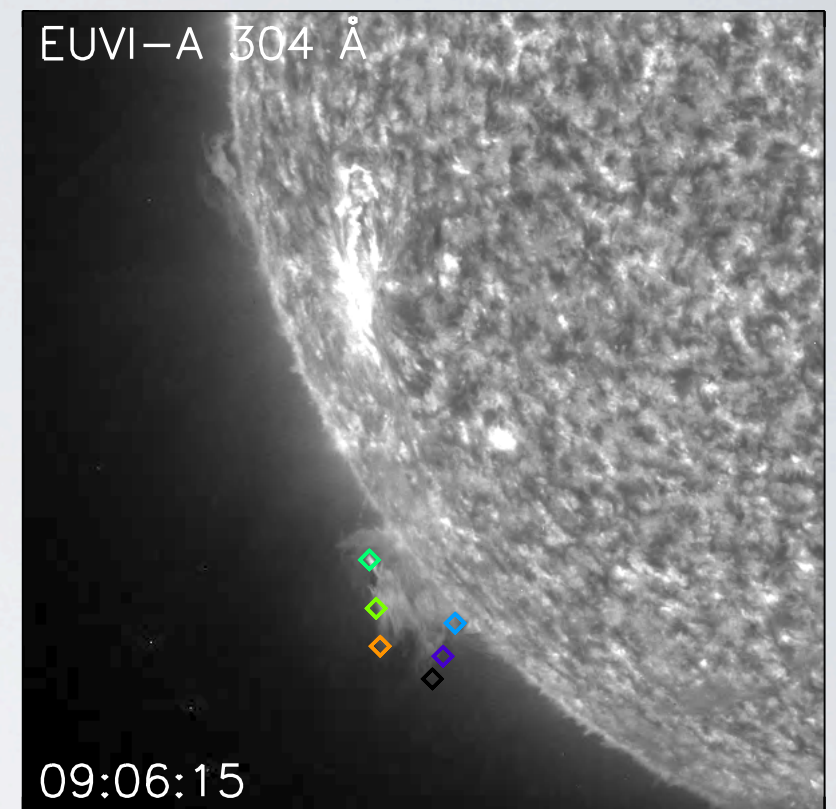
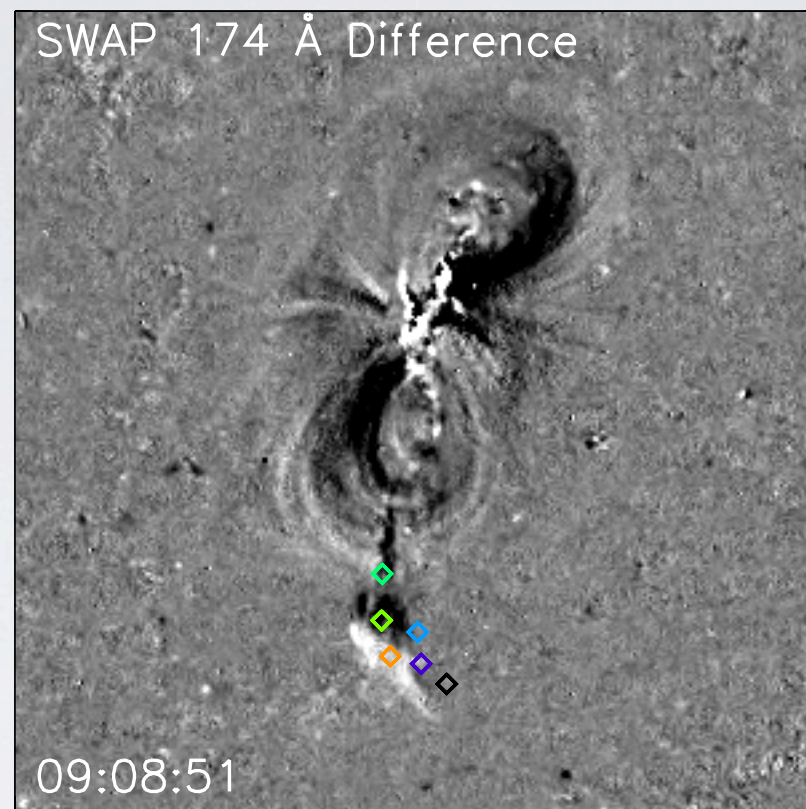
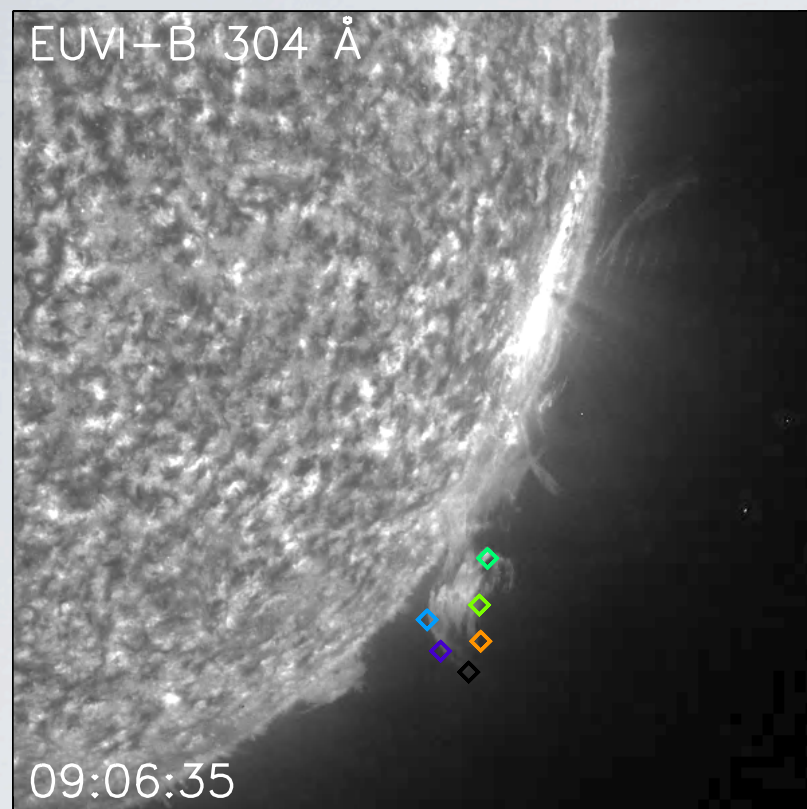
# MAKING RECONSTRUCTIONS



# THE FLUX ROPE

EUVI 195 Å  
SWAP 174 Å

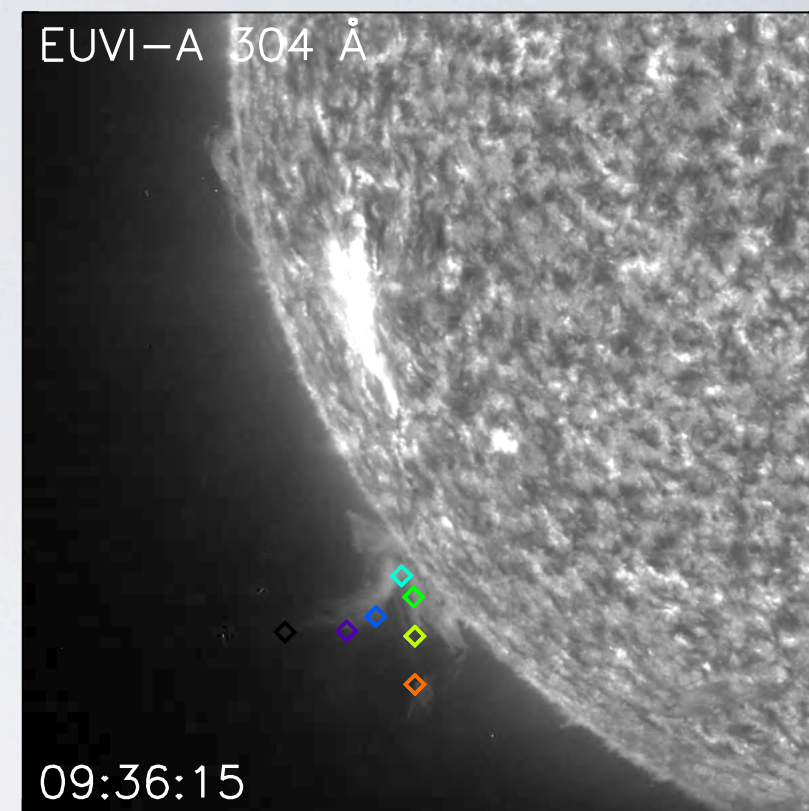
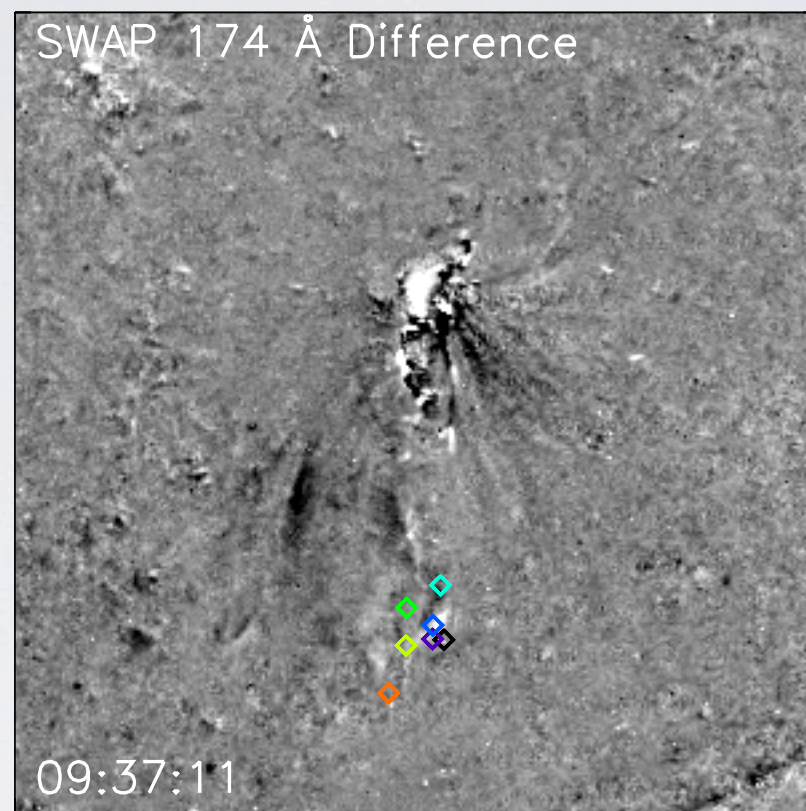
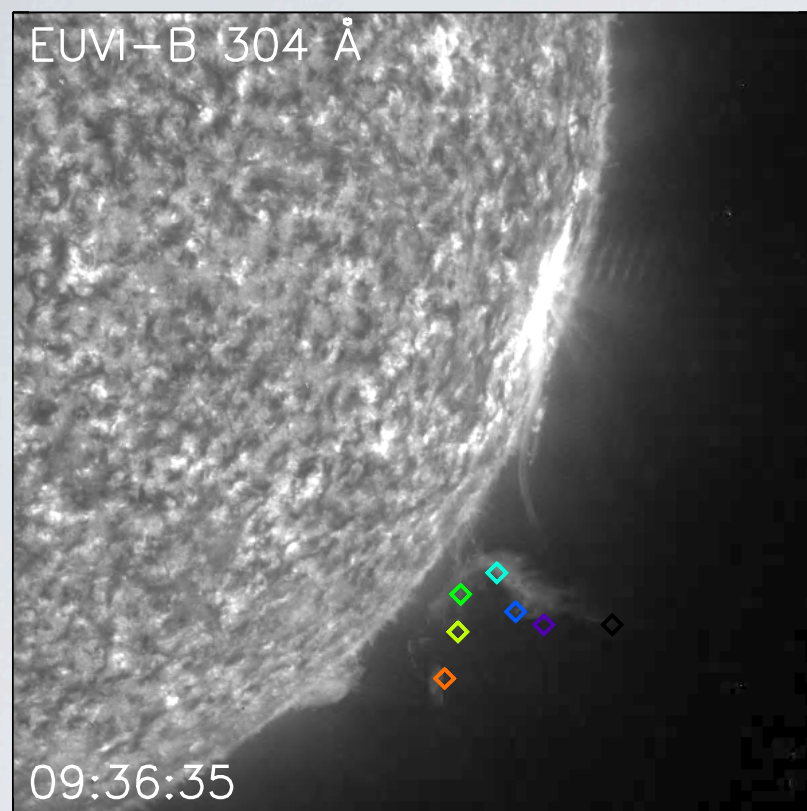




# THE MASS OFF-LOAD

EUVI 304 Å  
SWAP 174 Å Running Difference

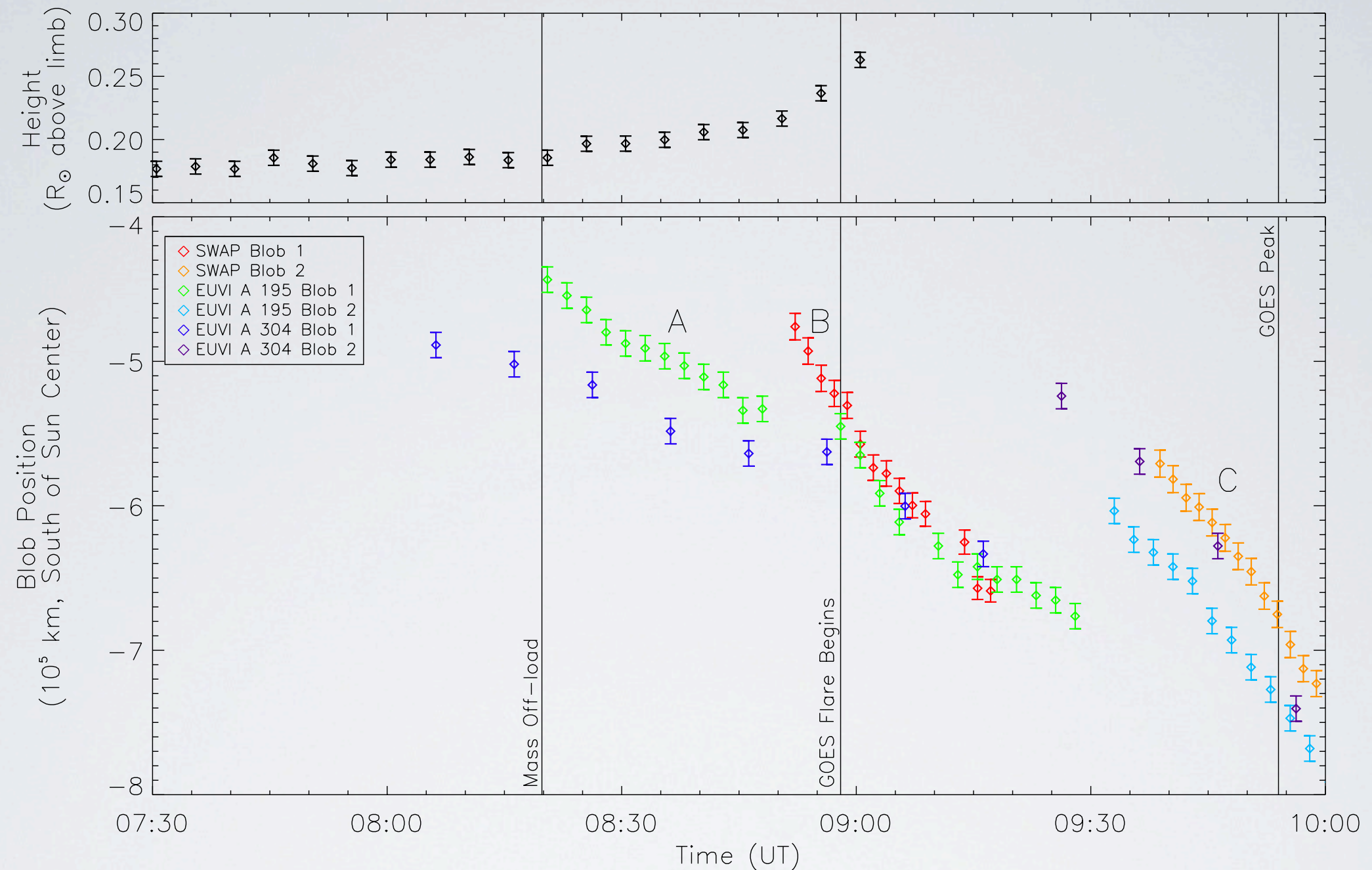




# THE ERUPTING REMNANTS

EUVI 304 Å  
SWAP 174 Å Running Difference





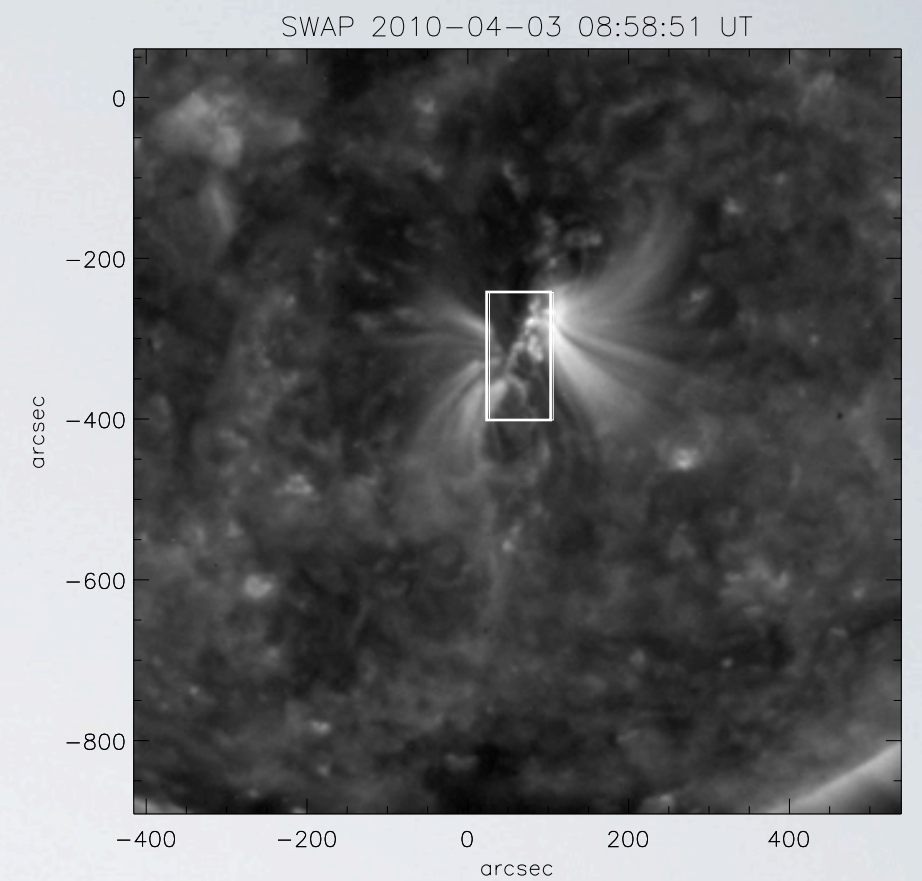
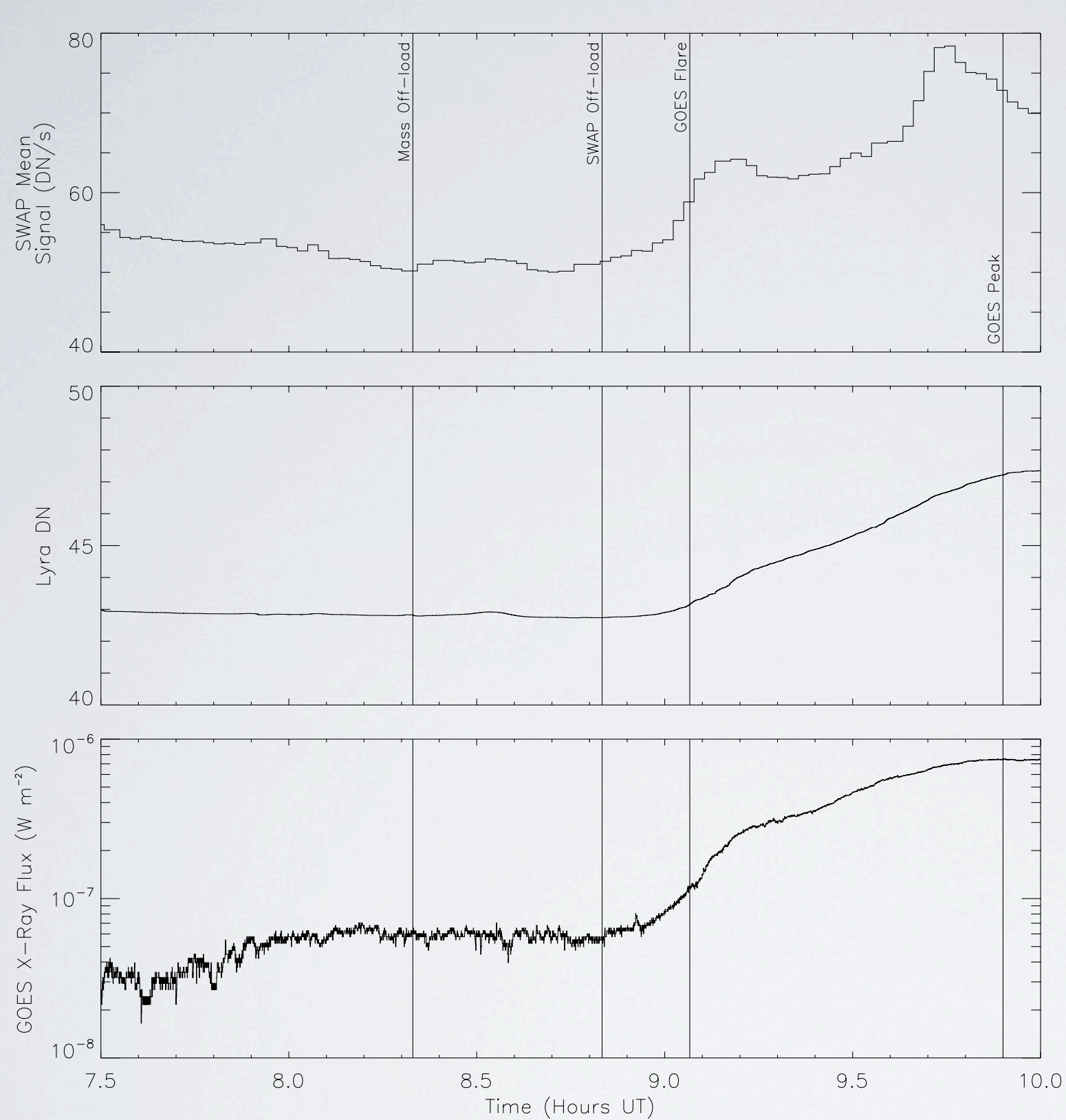
# OFFLOAD VS. FLUX ROPE

Top: Flux Rope Height vs. Time

Bottom: Southward Progress of 3 Plasma Blobs

HEATING





Top: SWAP Active Region Flux

Middle: LYRA Flux (10–200 Å)

Bottom: GOES X-Ray Flux

FLUX VS. TIME

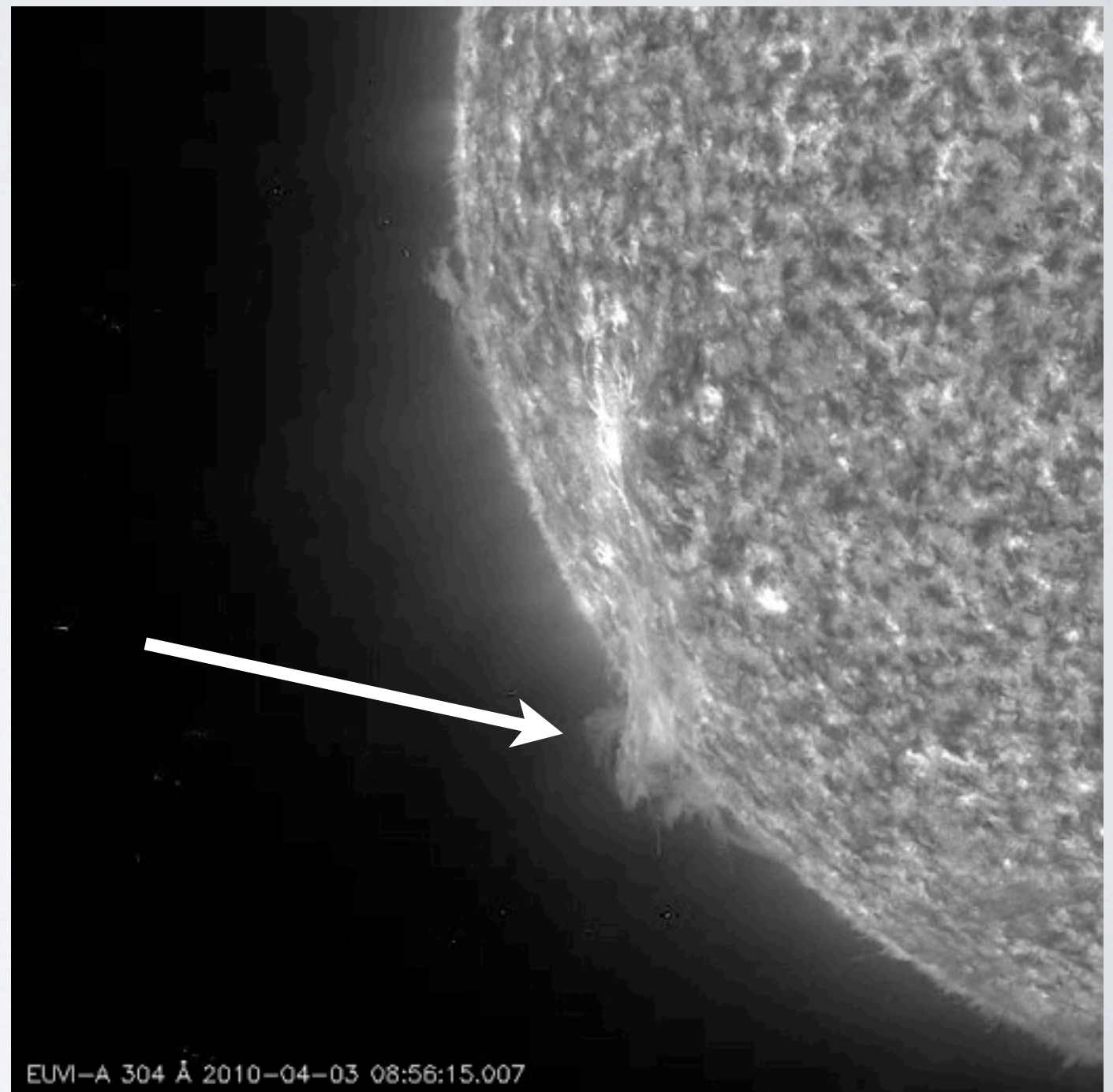
CAN WE NOW ANSWER OUR  
CENTRAL QUESTION?



# SUMMARY

# WHAT WE KNOW

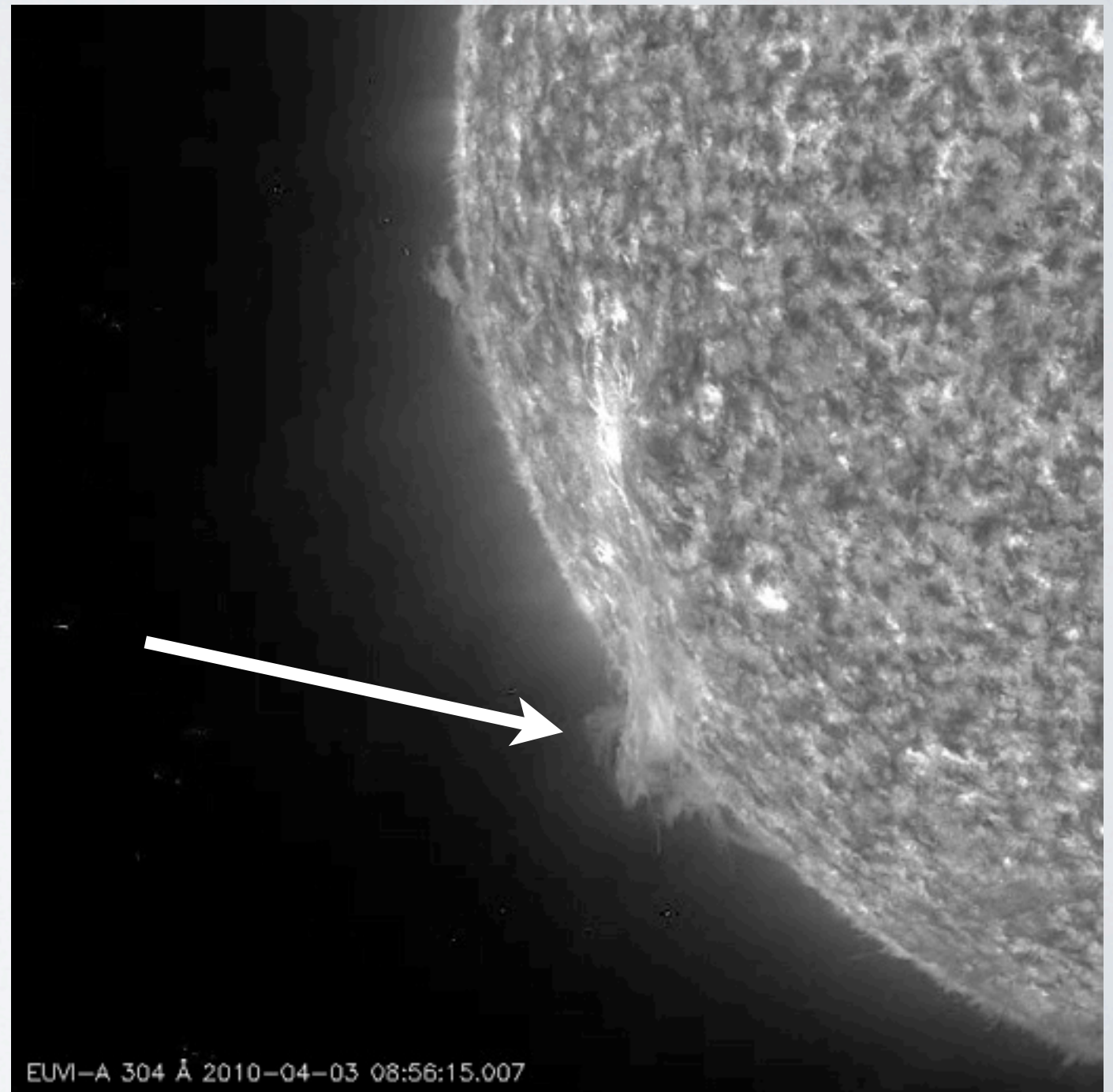
- Mass flow was cool & dense





# WHAT WE KNOW

- Mass flow originated at the bottom of the flux rope



# WHAT WE KNOW

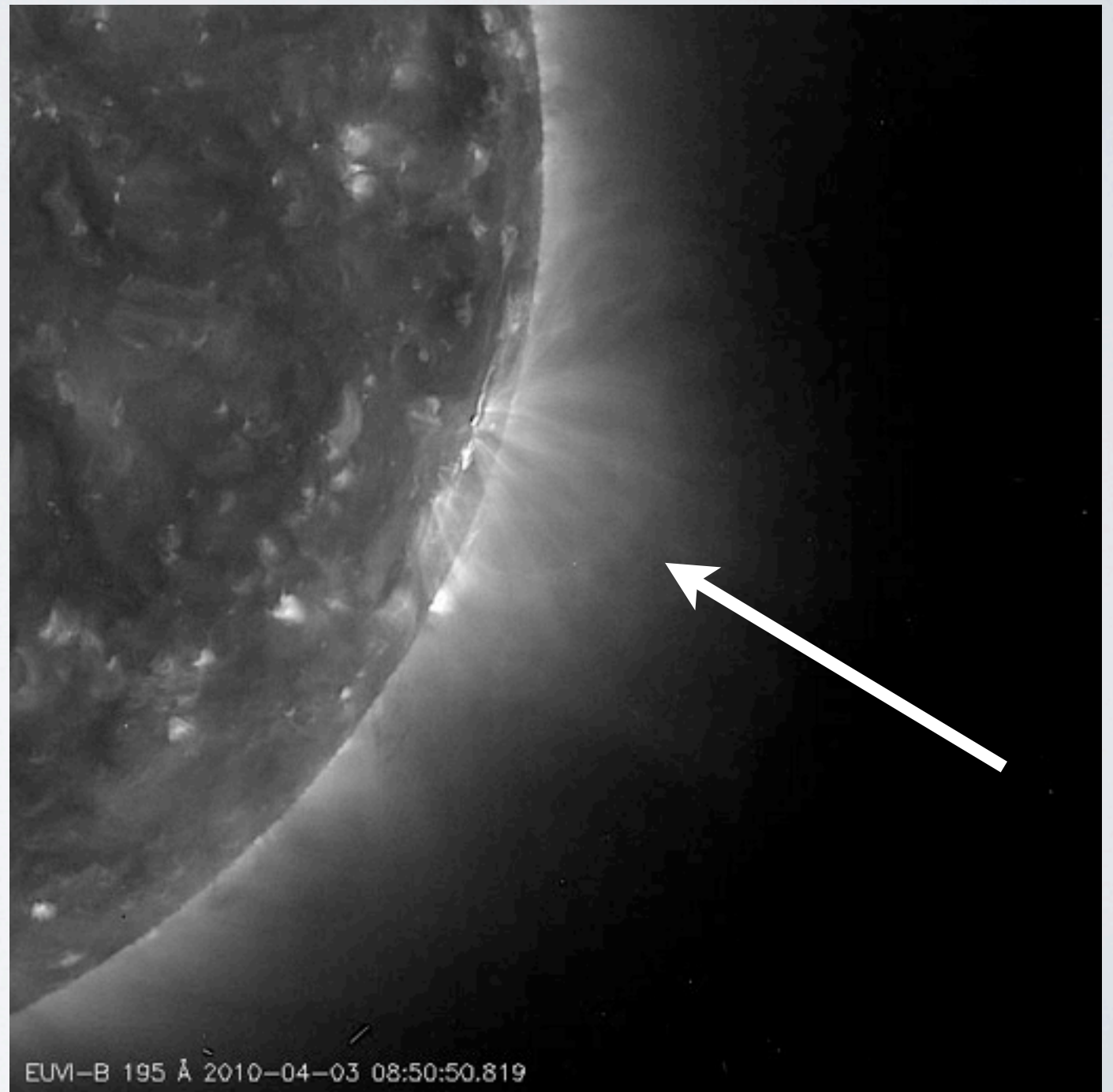
- Flow occurred immediately before flux rope rise began





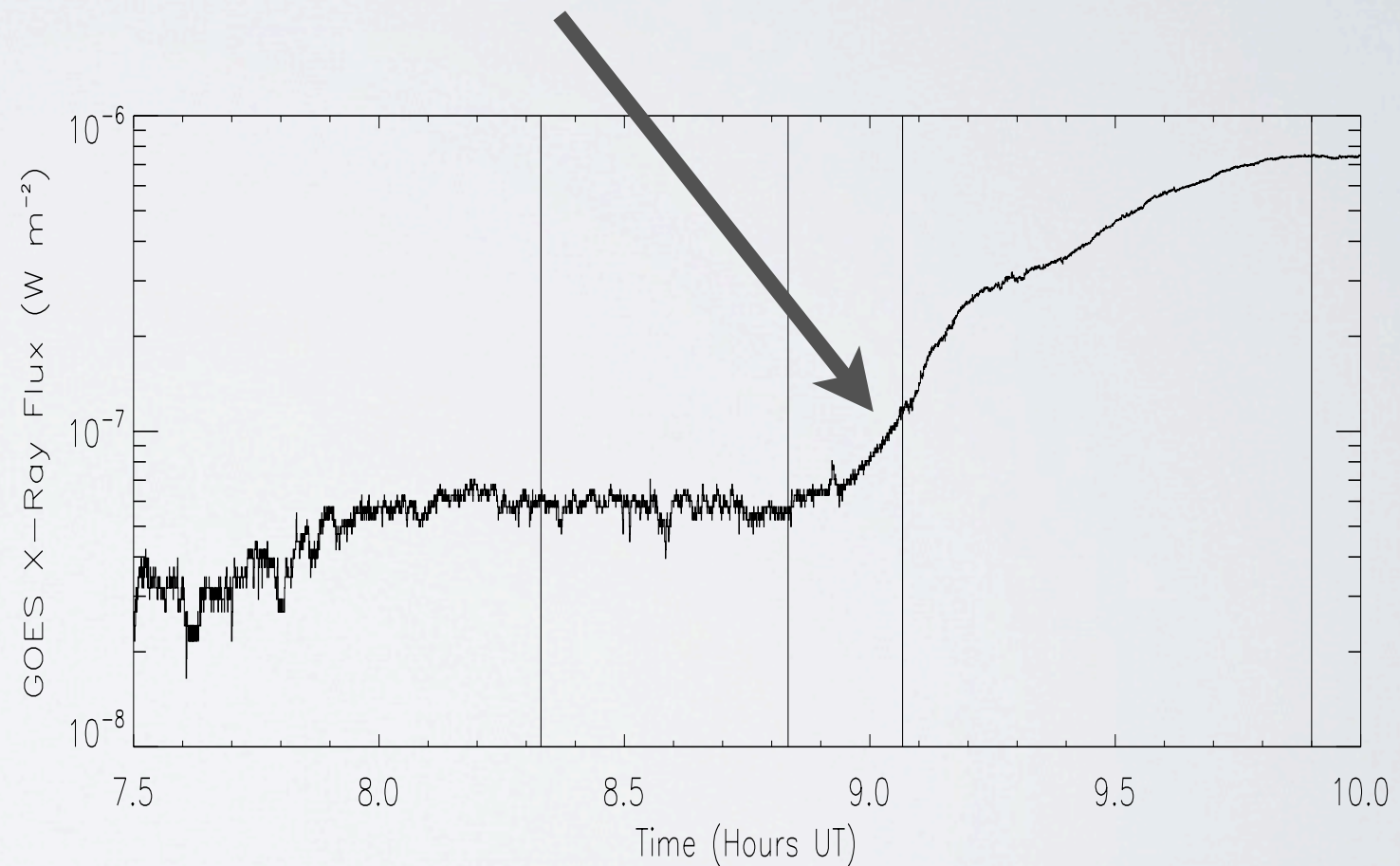
# WHAT WE KNOW

- Flux rope's initial rise was slow, then suddenly rapidly accelerated



# WHAT WE KNOW

- No significant brightening occurred before the flux rope eruption





# INTERPRETATION

# WHAT WE LEARNED

- Mass unloading removed dense material and lightened flux rope
- This allowed the flux rope to rise buoyantly
- Eventually this rise destroyed the equilibrium that anchored the flux rope in the corona and the eruption began
- Magnetic reconnection began during this phase, caused a solar flare, and accelerated the new CME



# THE ANSWER TO OUR CENTRAL QUESTION

# MASS UNLOADING CAUSED THE 3 APRIL 2010 ERUPTION\*

\* One event cannot explain all eruptions, this is just one of many mechanisms that can cause an eruption.



WHY IS THIS IMPORTANT?

STEREO-A COR1/2



STEREO Ahead COR1

2010-04-03 07:00:18

STEREO Ahead COR2

2010-04-03 07:39:00

STEREO-A COR1/2



STEREO Ahead COR1

2010-04-03 07:00:18

STEREO Ahead COR2

2010-04-03 07:39:00

STEREO-A COR1/2



THIS ERUPTION LAUNCHED  
THE CME THAT CAUSED THE  
GALAXY-15 EVENT

TWO QUICK ADS



FOR MORE ANALYSIS OF THIS  
EVENT SEE MIERLA ET AL.

*Multi-Spacecraft Observations of 3 & 8 April Coronal Mass Ejections*  
Poster Session 3



FOR MORE ABOUT SWAP & PROBA2

Visit the PROBA2 Poster this Afternoon

<http://proba2.oma.be/>